Report on the Workshop

# Feeding the Giants: ELTs in the Era of Surveys

held in Ischia (Napoli), Italy, 29 August – 2 September 2011

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**Over the next decade, an incredible wealth of data will become available through many ongoing and forthcoming survey facilities. At the same time, the three Extremely Large Telescope (ELT) projects (the European ELT [E-ELT], the Thirty Meter Telescope [TMT] and the Giant Magellan Telescope [GMT]) will open a new parameter space of unprecedented sensitivity and spatial resolution. Motivated by exploring synergies between these two approaches, the workshop drew together both the survey and the ELT communities to define the first strategies to maximise the success of both aspects. The workshop was jointly organised by OPTICON and the INAF Observatory of Rome, the University of Oxford and ESO, and was held on the island of Ischia, near Naples.**

The aim of the workshop was to address two broad questions: along with surveys conducted by current and forthcoming observatories, how will the upcoming dedicated survey facilities profit from follow-up by the ELTs; and to what extent do the three ELT projects require surveys to prepare for scientific breakthroughs? Both points were intensively discussed by about eighty international participants (from Europe, USA, Australia and Asia) over the five-day conference. We explored a range of forthcoming and ongoing facility projects and surveys, ELT instrumentation, as well as targeting a wide range of science areas (including exoplanets, stellar populations, galaxy formation and evolution, and cosmology) to address these two questions.

## The facility sessions

To set the scene, the conference opened with a comprehensive review of the facility landscape at the expected time of ELT operations, given by Patrick Roche, followed by invited reviews of the three ELT projects by Roberto Gilmozzi (E-ELT), Patrick McCarthy (GMT) and Timothy Davidge (TMT). All three projects are progressing well, undergoing cost and technical readiness reviews with planned first light early in the next decade.

The status of many ongoing and forthcoming facilities was then presented in detail by invited reviewers.

Thijs de Graauw presented a status update of the ALMA project, with the first call for proposals receiving around 900 applications; early science with the sixteen 12-metre antennas started on September 30. The Square Kilometer Array (SKA), presented by Lister Staveley-Smith, will be ready to enter the pre-construction phase in early 2012, and major science will already be possible with SKA1 in 2020 (10% of the full SKA). The synergies between these two facilities and the three ELTs were illustrated, highlighting, in particular, the comparable angular and spectral resolutions that will allow astronomers to perform multi-wavelength studies of astrophysical phenomena and objects, such as the gaseous evolution and dynamics of galaxies, star formation and discs around protostars.

The Large Synoptic Survey Telescope (LSST), presented by Philip Marshall, will have first light in 2018, and many of its projects would benefit from ELT follow-up, for example in providing spectra of newly detected transients, such as distant and exotic supernovae, or stellar velocity measurements in newly discovered low-mass Milky Way dwarf satellites.

Timo Prusti illustrated the advanced status of the Gaia project, which will be ready for launch in June 2013. This facility will provide astronomers with astrometry, photometry and radial velocities for at least one billion stars in the Milky Way, which will serve as an excellent astrometric reference frame with sub-milliarcsecond accuracy down to magnitudes of $V \sim 20$ for precise target selection with the ELTs.

Three other survey facilities, the Visible and Infrared Survey Telescope for Astronomy (VISTA), the VLT Survey Telescope (VST) and the Synoptic All Sky Infrared Survey (SASIR) were also presented during the first day's session. VISTA and VST are already in operation and conducting large public surveys addressing a variety of scientific questions.

Euclid, an M-class mission in the ESA Cosmic Vision Programme project, was also presented. This facility will survey the sky through optical and near-infrared imaging and slitless spectroscopy, with the primary goal of precision cosmology. These wide and deep surveys will deliver a wealth of other science including the discovery of rare objects that will be ideal targets for follow-up with ELTs.

## The science sessions

The following days of the workshop were devoted to seven science sessions, namely Solar System, Exoplanets, Stars and Milky Way, Stellar Astrophysics, Nearby Galaxies, Time Variability, Galaxy Evolution and Cosmology, each one introduced by an invited review. Roger Blandford opened the session presenting the scientific landscape of the next decade and future perspectives in light of limited resources.

Franck Marchis reviewed the current state of the art of Solar System science, which primarily originates from space missions that have probed the inner Solar System. Only one NASA mission, New Horizons, aimed at surveying Trans-Neptunian Objects (TNOs) is scheduled in the future, and another will observe Jupiter (Juno). There are no space missions towards the outer Solar System foreseen by countries that have just recently become involved in space studies. In this context, the ELTs, with their unprecedented angular resolution and sensitivity, will give access to the outer part of the Solar System from the ground. High angular imaging coupled with spectroscopy in the near infrared, for example, will allow the study of the surface

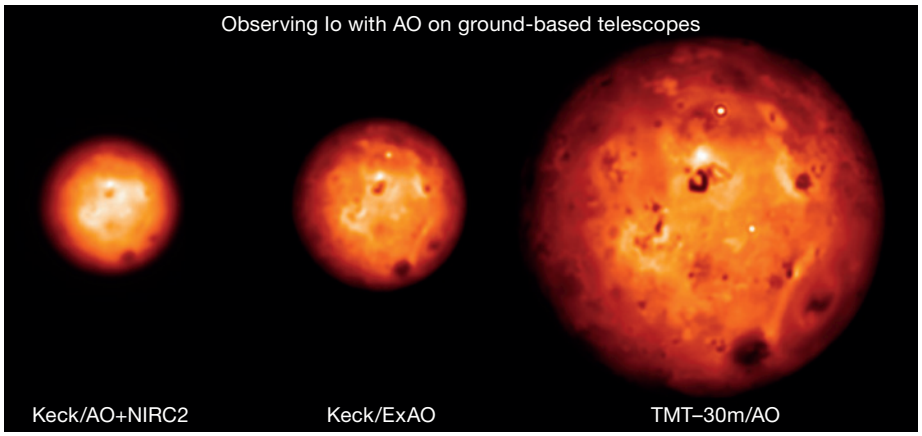


Figure 1. Simulations of the Jovian satellite Io as observed using adaptive optics with the Keck telescope using two techniques and with adaptive optics on the TMT. From Marchis et al., 2005.

composition and the volcanic activity of the Jovian satellite Io (see Figure 1), and to monitor the atmosphere of the satellite of Saturn, Titan, and of TNOs. On the other hand, mid-infrared spectroscopy will allow the analysis of molecular species in the atmospheres of Titan, Uranus and Neptune. Moreover, about half a million asteroids and comets are known today, and the sample will quickly increase thanks to the future ground- and space-based survey facilities. This large sample will require a spectroscopic follow-up by the ELTs, covering the wavelength range from the ultraviolet to the near-infrared (NIR), in order to provide an accurate taxonomic classification of these objects.

The topic of exoplanets was reviewed by Anne-Marie Lagrange, who showed how the ELTs will allow both indirect detection of low-mass Earth-like planets down to the habitable zone and direct detection of giant and Neptune-like planets. The characterisation of planets discovered by survey missions, through transits, direct imaging or spectroscopy, is a key science driver for the ELTs. These observations will allow the physical properties of the exoplanets to be constrained, such as mass, atmospheric composition and even weather in giant planets, on the path towards remote detection of exo-life.

In the field of stellar astrophysics, Manuela Zoccali showed in her review how large-scale surveys will be needed, with high spatial and spectral resolution, to characterise the Milky Way Bulge. The ELTs will be crucial for studying the abundances of the most metal-poor Bulge stars to check, for instance, whether they were the first stars to form in the Galaxy. Great advances will come from facilities such as Gaia, Skymapper, RAVE, Hermes, SOFIA, and LSST, which will provide accurate astrometry and multi-wavelength photometry. These data, together with the high-resolution spectroscopy at high angular scales provided by the ELTs, will allow different Galactic stellar components (thin and thick disc, Bulge and halo) to be disentangled, thereby allowing us to constrain how the Milky Way and other galaxies formed and evolved.

Giuseppe Bono highlighted in his review how the uncertainties in the distance measurements still strongly affect the age estimates of Galactic clusters, giving absolute ages with an accuracy of only about 1–2 gigayears. The precise estimate of absolute and relative ages of stellar clusters in the Milky Way is fundamental to constrain the formation scenario of the Galaxy and to provide a lower limit to the age of the Universe. The high-resolution images collected by the future ELTs with the help of adaptive optics techniques will provide deep and accurate optical–NIR colour–magnitude diagrams (CMDs) of both Galactic clusters and Local Group stellar systems. These will be crucial to fully exploit the potential of diagnostics, such as the white dwarf cooling sequence or the bending of the lower main sequence, in providing absolute and relative ages.

For nearby galaxies, Carme Gallart's review illustrated that targeted surveys, together with ELT deep photometry and low/intermediate resolution spectroscopy, will be essential. The ultimate goal will be to derive star formation histories of galaxies in different environments. In order to derive accurate star formation histories, CMDs reaching the old main sequence turn-offs will be needed. With the ELTs this goal will be achieved in galaxies belonging to nearby groups, while for a representative sample of galaxies in the Virgo cluster (at a distance of about 16 megaparsecs), issues such as the effect of galaxy interactions on star formation might be addressed. More importantly, the ELTs will allow resolution of stars in these distant galaxies at surface brightness values currently not accessible to any other ground- or space-based facility. Furthermore, low-resolution spectroscopy of red giant branch stars will allow the chemical composition of old stellar populations to be traced out to the distance of the Virgo and Fornax galaxy clusters, while low-resolution spectroscopy of luminous super-giants will provide accurate chemical compositions for stars in galaxies well beyond these clusters.

Driven by technological innovation, wide-field astronomy has witnessed a resurgence, with a multitude of surveys being carried out and planned for the next decade; these surveys can investigate time-variable sources in the Universe. In his invited review, Shrinivas Kulkarni highlighted that, along with depth and area, cadence should be a standard parameter in the description of a survey, as this is the quantity that drives the frontiers in the research of time-variable phenomena. Ongoing surveys have largely filled in the gap between the rare but bright supernovae (SNe) and the faint but common classical novae with a host of objects (core-collapse SNe, thermo-nuclear SNe, calcium-rich transients, red novae, SNIa explosions, SNe and gamma-ray burst [GRB] afterglows), but the domain of short time-scales (less than one day) remains largely unexplored. While a number of surveys are planned, the subject would benefit from a co-ordinated multi-facility and multi-wavelength approach to make real

progress in understanding time-variable phenomena.

The ELTs will play a pivotal role in identifying and characterising transients (on all timescales) that are faint in the optical/NIR, up to about six magnitudes fainter than is currently possible. Optical–NIR follow-up of transient sources (e.g., pulsars, SNe/GRB afterglows) and their faint progenitors or host galaxies, identified by, for example, LSST, FERMI, SWIFT, GLAST and LOFT, will open a new era in understanding the properties of transient sources as well as opening new fields, such as the connection of short timescale GRBs to gravity wave experiments, mapping the magnetospheres and magnetic fields of pulsars via polarimetric observations and faint probes of the (very) high-redshift intergalactic medium.

In his invited review, Carlos Frenk discussed both theoretical predictions of galaxy formation and evolution models and the observational advances made in these fields. Together with sensitive concurrent facilities, the ELTs will play a crucial role in galaxy evolution both at the highest redshifts and at the faintest flux levels, as well as in unprecedented spatial resolution via adaptive-optics assisted observations. The session on galaxy evolution and cosmology comprised talks on a range of multi-wavelength approaches to the topic covering detailed analysis at high spatial resolution of the dynamical state of galaxies, infrared photometric and spectroscopic surveys with Spitzer, Herschel and SPICA, sensitive radio measurements of star-forming galaxies with the SKA and its pathfinders, and the search for galaxies at the highest redshifts.

The synergies between large-area sensitive surveys with future facilities, including the James Webb Space Telescope (JWST) and SKA, in finding large samples of galaxies at high redshift were discussed, as well as the complementarity in spatial resolution to ALMA. With the ELTs we will be moving to detailed studies of large samples of galaxies. The ELTs will push the redshift barrier to the earliest galaxies, providing key constraints on the sources of first light. They will potentially reach objects dominated by Population III stars and probe the evolution of the intergalactic medium out to the era of reionisation.

Joseph Caruana

Figure 2. The conference photo taken at the venue on Ischia on 31 August 2011.

A session of the workshop was also devoted to future instrumentation. The session comprised talks devoted to wide-field spectrographs for 4-metre-, 8-metre- and ELT-class telescopes (WEAVE, MOBIE and MANIFEST) from both the technological perspective and the key scientific motivations. In addition, the multi-conjugate adaptive optics module MAORY for the E-ELT (see Diolaiti, 2010) was discussed, with an emphasis on the possibility of correcting the image quality over a field of view as large as possible. HARMONI, an optical to near-infrared integral field spectrograph for the E-ELT (see Thatte, 2010) was also presented. As well as a pixel scale that suits seeing-limited conditions, HARMONI’s finest pixel scale can make use of adaptive optics to achieve diffraction-limited observations with this telescope, providing a strong complementarity to ALMA. *The Messenger* 140 provides summaries of all the E-ELT instrument concepts.

The workshop also issued a statement in support of JWST, since the majority of astronomers were particularly concerned by the risk of cancellation of the JWST project, and by the impact that the loss of scientific capability would have on the astronomical community worldwide.

## Closing discussion

The discussion was organised as a World Café[1]. Astronomers were divided into tables of about seven for three rounds of 20-minute discussions around proposed questions. Each table had a leader who took notes and summarised the discussion at the end. Gerry Gilmore summarised the discussion and provided conclusions for the Café.

Many interesting points were raised during this open and relaxed discussion, in particular, regarding how to deal with future observing programmes, data mining of surveys, and sharing technology and capability. It was emphasised how the follow-up of surveys with the ELTs will be crucial in the search for optical–NIR counterparts of extragalactic sources detected in the submillimetre, radio and X-ray, in characterising the faintest stars and brown dwarfs in the Milky Way and in the Local Group galaxies, in providing transit spectroscopy of newly detected exoplanets, or in identifying sources of gravitational waves. On the other hand, the impact of the ELTs will be maximised by surveys producing accurate astrometry and radial velocities of large samples of exoplanets and stars in the Milky Way, or by wide-field imaging

and spectroscopic surveys identifying the first galaxies, rare quasars, supernovae and gamma-ray bursts.

A lively discussion arose on data policy and data mining for surveys and ELTs. Most participants agreed that proprietary time should be at the minimum level but sufficient to guarantee intellectual ownership and a satisfactory progress of the surveys and the ELTs. Others proposed to have the data public from the beginning. In order to facilitate data mining, it was proposed that all data provided by the surveys and the ELTs should be Virtual Observatory compliant from the outset. Another interesting discussion was about ELTs sharing their development efforts through common documentation, complementary instrumentation capabilities, sharing information on site monitoring and sharing observing time.

The third part of the discussion dealt with how to retain diversity and how to involve young people in the era of flagship projects. Astronomers agreed that a large fraction of open time should be available at the ELTs, together with encouraging some explicitly high-risk projects. It was noted that is very important to retain a broad range of facilities, including 4-metre- and 8-metre-class telescopes, to be used as survey facilities, to promote small projects, and to train young astronomers. All the long-term flagship projects should try to involve more students and young researchers, allowing them to attend science working committees, and communicating the outcome of the major high-level decisional meetings to them. Furthermore, it was proposed that at least one young astronomer should be included in each of the ELT science committees. More resources should be allocated to provide for longer term contracts to leave young astronomers more time to develop new and creative ideas.

Richard Ellis, in summarising the conference, highlighted the opportunity to establish a better coordination of facilities, instrumentations and programmes and that we should further strengthen these collaborations in the future. He also emphasised the power of emerging countries and public outreach for investments in astronomical research and that diversity in facilities and astronomical capabilities should be retained together with large-scale projects. Ellis reminded us that we cannot plan the future in detail and so optimism, versatility and creativity remain the key attributes for success.

All the presentations and the conference picture are available at the conference website: http://www.eso.org/sci/meetings/2011/feedgiant.

## References

Diolaiti, E. 2010, The Messenger, 140, 28
Marchis, F., Spencer, J. R. & Lopes, M. C. 2005, in *Io after Galileo*, eds. R. M. C. Lopes and J. R. Spencer, Springer, p.287
Thatte, N. 2010, The Messenger, 140, 26

## Links

[1] More about the World Café format at: http://www.theworldcafe.com/

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Report on the ESO/MPE/MPA/ExcellenceCluster/LMU Joint Astronomy Workshop

# The Formation and Early Evolution of Very Low-mass Stars and Brown Dwarfs

held at ESO Headquarters, Garching, Germany, 11–14 October 2011

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**The topics discussed at the workshop ranged from the structure and fragmentation of molecular clouds to the formation of individual very low-mass objects, their multiplicity, physical structure, mass distribution and early evolution. Each topic was introduced by two reviews on the status of our theoretical and observational understanding of the field, followed by presentations of new results and discussions. In this report we provide a brief summary of some of the areas discussed at the workshop.**

Very low-mass (VLM) stars (< 0.4 $M_{\odot}$) and brown dwarfs (BDs) are faint objects with low effective temperatures which are difficult to detect due to their low luminosities ($\lesssim$ 0.01 $L_{\odot}$). On the other hand, these objects are the major constituents of the stellar population of any galaxy and outnumber higher-mass stars by factors of hundreds to thousands. Current wide area surveys in nearby molecular clouds, from optical to far-infrared wavelengths, provide exciting new information on the process of the formation and early evolution of VLM stars and BDs. We report on the ESO/MPE/MPA/LMU/ExcellenceCluster joint workshop dedicated to recent theoretical and observational advances made in the field of study of the formation and early evolution of brown dwarfs and very low-mass stars.

It was demonstrated in several talks that, with the help of new and powerful ground- and space-based facilities (e.g., VISTA and Herschel respectively), we are starting to discover young VLM stars and BDs and their precursors in numbers large enough to allow statistical analyses of their properties. In addition, detailed studies of individual objects and small samples are now effectively being